TOPIC 04 – BONDING
4.1 – IONIC BONDING

IB Chemistry

T04D01

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4.1 – Ionic Bonding

- 4.1.1 Describe the ionic bond as the electrostatic attraction between oppositely charged ions. (2)
- 4.1.2 Describe how ions can be formed as a result of electron transfer. (2)
- 4.1.3 Deduce which ions will be formed when elements in groups 1, 2 and 3 lose electrons. (3)
- 4.1.4 Deduce which ions will be formed when elements in groups 5, 6 and 7 gain electrons. (3)
- 4.1.5 State that transition elements can form more than one ion. (1)
- 4.1.6 Predict whether a compound of two elements would be ionic from the position of the elements in the periodic table or from their electronegativity values. (3)
- 4.1.7 State the formula of common polyatomic ions formed by nonmetals in periods 2 and 3. (1)
- 4.1.8 Describe the lattice structure of ionic compounds. (2)

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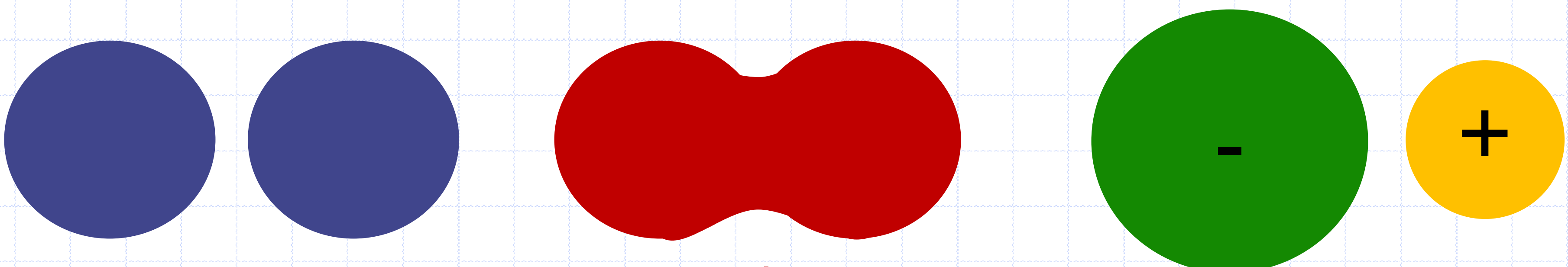
Definition of an Ionic Bond

4.1.1 Describe the ionic bond as the electrostatic attraction between oppositely charged ions. (2)

- **Ionic bonding** occurs when one or more electrons are **transferred** from the valence shell of one atom to another.
  - The atom losing electrons forms a negative ion (Anion)
  - The atom gaining electrons forma a positive ion (Cation)
- DEF: An **ionic bond** is the electrostatic interaction between oppositely charged ions



Separate atoms

Covalent Molecule

Ionic Compound (Ions)

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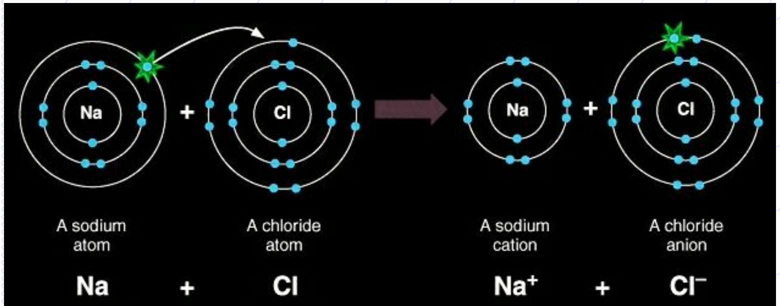
How Ions are formed

4.1.2 Describe how ions can be formed as a result of electron transfer. (2)

- The formation of an ionic compound involves the reaction between a metal and a non-metal
- For example in the formation of sodium chloride
  - Sodium atom, Na 2.8.1
  - Chlorine atom, Cl 2.8.7
- The ionic bond occurs when the valence electron from the 3rd shell of Na are transferred to the 3rd shell of Cl
  - Sodium ion, Na^+ 2.8
  - Chloride ion, Cl^- 2.8.8
- Each ion now has a stable Noble Gas electron arrangement



Ionic Bonding – Examples: Transferring electons

$1s^2 2s^1$ $\quad$ $1s^2$

$\bullet Li + :\dot{F}: \longrightarrow Li^+ :F:^-$

$1s^2 2s^2 2p^5$ $\quad$ $1s^2 2s^2 2p^6$

Ionization of Lithium:

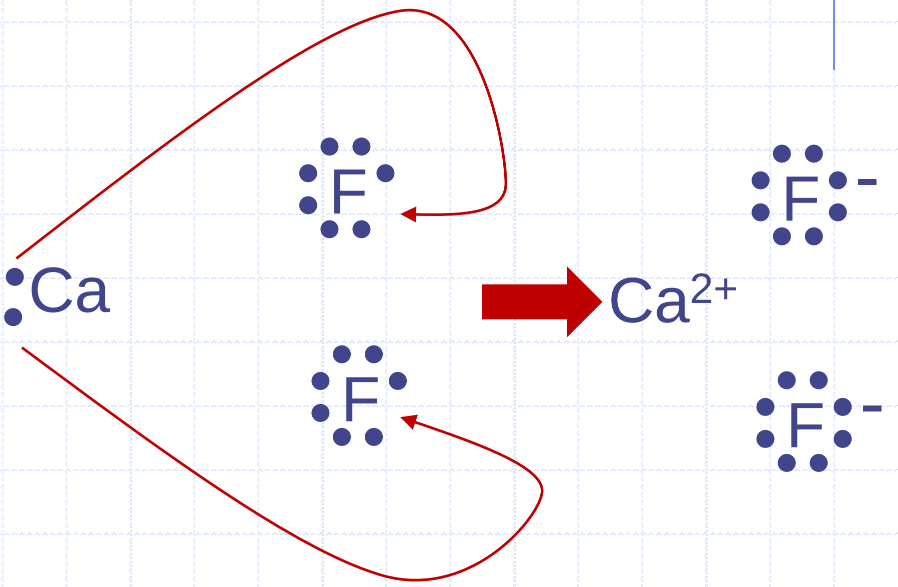
[He]

$\bullet Li \longrightarrow Li^+ + e^-$

Electron Affinity of Fluorine:

[Ne]

$e^- + :\dot{F}: \longrightarrow :F:^-$



Common Ions of Metals

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4.1.3 Deduce which ions will be formed when elements in groups 1, 2 and 3 lose electrons. (3)

- Metals lose electrons to form positively charged cations
  - Low ionization energies due to large radius and electron shielding compared to nuclear charge
- The number of valence electrons determines the most common oxidation state

Cations	**Name**
H^{+}	Hydrogen
Li^{+}	Lithium
Na^{+}	Sodium
K^{+}	Potassium
Mg^{2+}	Magnesium
Ca^{2+}	Calcium
Ba^{2+}	Barium
Al^{3+}	Aluminum

Common Ions of Non-Metals

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4.1.4 Deduce which ions will be formed when elements in groups 5, 6 and 7 gain electrons. (3)

- Non-metals gain electrons to form negatively charged anions
  - High ionization energies allow non-metals to hold onto their electrons
  - The electronegativity is high (compared to metals) as their atomic radius is small due to increased nuclear charge relative to electron shielding
  - Easier to hold onto electrons that are closer
  - Number of valence determined the charge

Anions	**Name**
O^{2-}	Oxide
F^-	Fluoride
Cl^-	Chloride
Br^-	Bromide
N^{3-}	Nitride
I^-	Iodide
S^{2-}	Sulfide
P^{3-}	Phosphide

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Oxidation States of Transition Metals

4.1.5 State that transition elements can form more than one ion. (1)

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
								+1	
	+2	+2	+2	+2	+2	+2	+2	+2	+2
+3		+3	+3		+3	+3			
	+4	+4		+4					
		+5							
			+6	+6					
				+7					

- Nomenclature of transition metals demonstrate the oxidation state:
  - Copper (II) sulfate = Cu^{2+} and SO_4^{2-} = $CuSO_4$
  - Copper (III) chloride: Cu^{3+} and Cl^- = $CuCl_3$

What type of bond?

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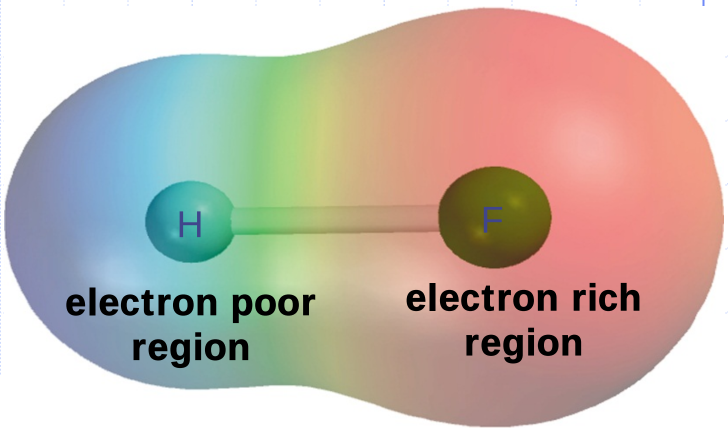
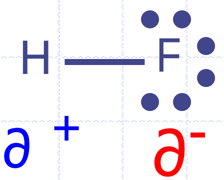
4.1.6 Predict whether a compound of two elements would be ionic from the position of the elements in the periodic table or from their electronegativity values. (3)

- Rough range difference in electronegativity
- 0 is Non-Polar Covalent
  - Even sharing
- 0 > Diff < 1.8 is Polar Covalent
  - Uneven sharing
- Diff > 1.8 is Ionic
  - transfer of electrons



e^- poor e^- rich



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
H 2.1																
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.8	Ba 0.9	La* 1.1	Hf 1.3	Ta 1.5	W 2.4	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9	Ac† 1.1														

Legend: below 1.0; 1.0–1.4; 1.5–1.9; 2.0–2.4; 2.5–2.9; 3.0–4.0

*Lanthanides: 1.1–1.3
†Actinides: 1.3–1.5

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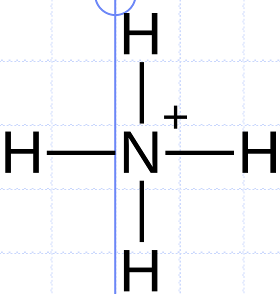
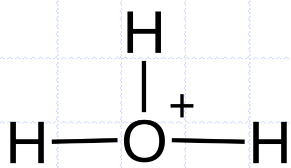
Polyatomic Ions

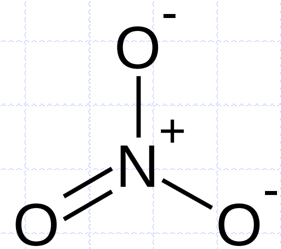
4.1.7 State the formula of common polyatomic ions formed by nonmetals in periods 2 and 3. (1)



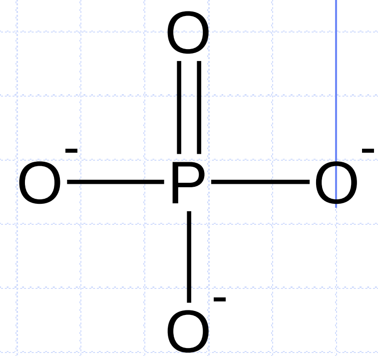
Ammonium NH_4^+
Ex: NH_4Cl



Hydronium H_3O^+
Ex: H_3OCl (HCl)

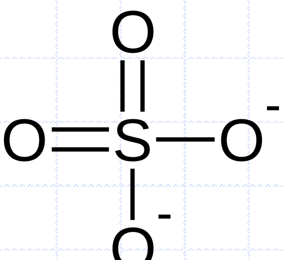


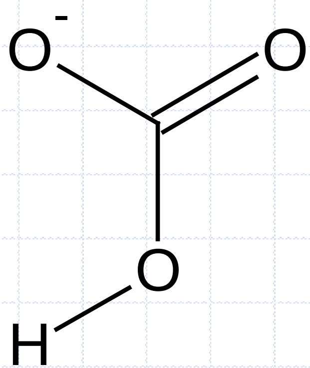
Nitrate NO_3^-
Ex: $AgNO_3$



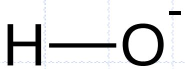
Phosphate PO_4^{3-}
Ex: K_3PO_4

Sulfate SO_4^{2-}
$MgSO_4$

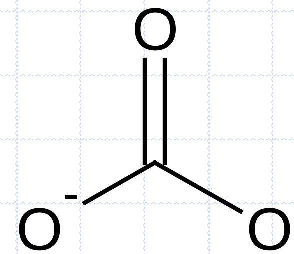




Hydrogen Carbonate
HCO_3^- Ex: $KHCO_3$



Hydroxide OH^-
Ex: NaOH



Carbonate CO_3^{2-}
Ex: Na_2CO_3

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There are many Polyatomic Ions

(1+) CATION	(1-) ANION	(2-) ANION	(3-) ANION
Ammonium NH_4^+	Chlorate ClO_3^-	Carbonate CO_3^{2-}	Phosphate PO_4^{3-}
Hydronium H_3O^+	Chlorite ClO_2^-	Sulfate SO_4^{2-}	Phosphite PO_3^{3-}
	Hydroxide OH^-	Sulfite SO_3^{2-}	Citrate $C_6H_5O_7^{3-}$
	Nitrate NO_3^-	Hydrogen phosphate HPO_4^{2-}	Ferricyanide $Fe(CN)_6^{3-}$
	Nitrite NO_2^-	Oxalate $C_2O_4^{2-}$	Arsenate AsO_4^{3-}
	Acetate CH_3COO^- or $C_2H_3O_2^-$	Chromate CrO_4^{2-}	Borate BO_3^{3-}
	Cyanide CN^-	Dichromate $Cr_2O_7^{2-}$	
	Hydrogen bi-carbonate HCO_3^-	Thiosulfate $S_2O_3^{2-}$	
	Hydrogen bi-oxalate $HC_2O_4^-$	Molybdate MoO_4^{2-}	
	Hypochlorite ClO^-	Peroxydisulfate $S_2O_8^{2-}$	
	Hydrogen bi-sulfide HS^-	Silicate SiO_3^{2-}	
	Hydrogen bi-sulfate HSO_4^-	Tartrate $C_4H_4O_6^{2-}$	
	Hydrogen bi-sulfite HSO_3^-	Peroxidate O_2^{2-}	
	Dihydrogen bi-phosphate $H_2PO_4^-$		
	Permanganate MnO_4^-		
	Iodate IO_3^-		
	Bromate BrO_3^-		
	Thiocyanate SCN^-		
	Periodate IO_4^-		
	Perchlorate ClO_4^-		
	Perbromate BrO_4^-		

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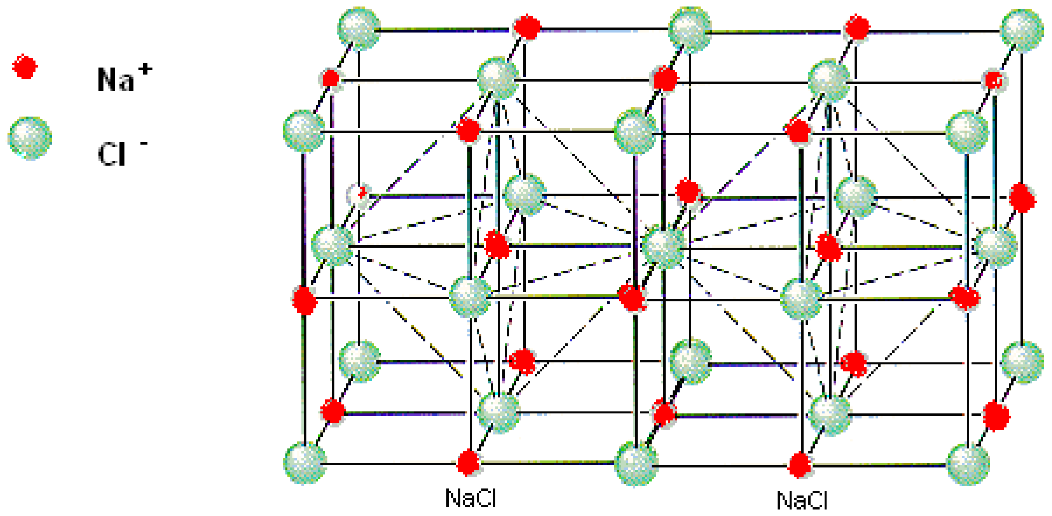
Lattice Structures

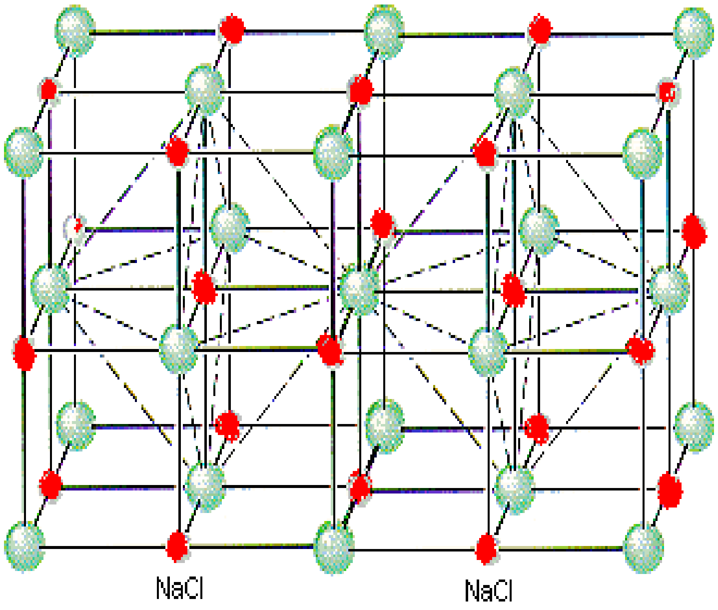
4.1.8 Describe the lattice structure of ionic compounds. (2)

- Ionic bonds result from the attractions between positive and negative ions.
- Ionic bonding involves 3 aspects:
  1. loss of an electron(s) by one element,
  2. gain of electron(s) by a second element,
  3. attraction between positive and negative



Ionic Bonding

- The shape and form of the crystal lattice depend on several factors:



- The size of the ions
- The charges of the ions
- The relative numbers of positive and negative ions

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Strength of ionic Bonds

- The strength of an ionic bond is determined by the charges of the ions and the distance between them.
- The larger the charges and the smaller the ions the stronger the bonds will be
- Bond strength then is proportional to

$$\frac{Q1 \times Q\,2}{r^2}$$

Where Q1 and Q2 represent ion charges and r is the sum of the ionic radii.

**Although this is not needed for IB, you should understand the concept

Writing Ionic Compound Formulas

Example: Magnesium sulfide

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

4. Write the formula without charges

$Mg^{2+}S^{2-}$

balanced!

MgS

Writing Ionic Compound Formulas

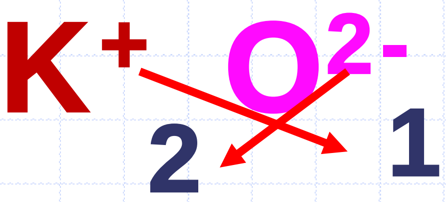
Example: Potassium Oxide

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

4. Write the formula without charges



Not balanced!

K_2O

Writing Ionic Compound Formulas

Example: Beryllium Nitride

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

$Be^{2+}N^{3-}$

3 2

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

Not balanced!

4. Write the formula without charges

$$Be_3N_2$$